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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of:

Amendment of the Commission's Rules to Provide for Unlicensed NII/SUPERNet Operations in the 5 GHz Frequency Range	)))	ET Docket No. 96-102 RM-8648 RM-8653

Comments of Motorola, Inc. DOCKET FILE COPY ORIGINAL

Motorola, Inc. hereby files its comments on the Notice of Proposed Rulemaking in the above-captioned proceeding. Therein, the Commission has proposed to allocate 350 MHz of spectrum at 5 GHz to support the operation of unlicensed, short-range, high speed wireless communications. Motorola supports the proposed spectrum allocation and recommends modifications to the proposed rules.

Respectfully Submitted,

Stuart E. Overby
Assistant Director, Spectrum Planning
Motorola Inc.
1350 I Street, N.W., Suite 400
Washington, D.C. 20005
(202) 371-6940

Leonard S. Kolsky
Vice President and Director,
Global Telecommunications Relations
Motorola, Inc.
1350 I Street, N.W., Suite 400
Washington, D.C. 20005
(202) 371-6932

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Executive Summary

The proposed allocation of 350 MHz of spectrum in the 5.15-5.35 and 5.725-5.875 GHz bands has the potential to spur development of a host of broadband multimedia products for on-site and local area use. These products should enable the free flow of broadband, high speed multimedia information within a number of venues including homes, schools, and health care facilities. For example, this spectrum could support a wireless localized in-home platform which offers broadband untethered connections among computers, televisions, appliance automation products, and on-premise network cable or telco access points. In a school or health care environment, similar products could be developed to meet the specialized on-site communications requirements of students, teachers, counselors, librarians, nurses, doctors and administrators.

Low power community network links in the 5.8 GHz band segment could expand some of these communications solutions by connecting buildings in a campus environment. Given the spectrum location, low power and open access nature of the proposal, Motorola views both on-premise systems and campus community links as a complement to, rather than a replacement for, licensed communications solutions. Motorola supports the Apple and WINForum position that the industry can develop technical guidelines and methodologies that will allow community network systems and on-site systems to share the unlicensed band, as long as sufficient, usable spectrum is allocated.

It is extremely important that the Commission adopt a minimalist regulatory structure for this allocation, given the broad variety of potential multimedia applications this spectrum could support. Without an expansive view of the potential uses of this band from the outset, the rules adopted could inadvertently stifle development of a number of communications solutions beneficial to consumers. As Motorola details in the following sections of these comments, we recommend the Commission:

- Allow for both on-site and community network communications solutions;

- Refrain from requiring a "listen-before-talk" etiquette which could inadvertently retard spectrum efficiency and limit the variety of products developed for this band;

- Allow a maximum transmitter power of 250 mWatts at 5.2 GHz and 1 Watt at 5.8 GHz for bandwidths above a certain threshold, e.g., 25 MHz;

- Allow directional gain antennas for transmitters in both 5 GHz bands to provide reliable communications and lower levels of interference;

- Allow, but not require a specific channelization scheme, as the bandwidth required is dependent on the data rate, communications distance, type of modulation, and specific error correction coding involved;

- Refrain from adopting a 1 bit/sec/Hz efficiency requirement, as the real efficiency is strongly related to frequency reuse;

- Adopt the proposed safe-harbor mechanism under which 5 GHz devices may operate without the risk of routinely being subject to a "non-interference only" status;

- Streamline the equipment approval process, avoiding regulatory delays in bringing all products to consumers; and

• Charge an industry committee such as WINForum or ATM Forum to address limits and measurement methods relative to out of band emissions, frequency stability, and power spectral density.

We believe such a rule structure will allow and actually encourage investment in the widest array of multimedia solutions which in aggregate, will serve the broadest cross-section of American consumers. In addition, such a structure should establish a very competitive equipment market, as telecommunications equipment, computer, home entertainment, home automation and software developers will all have maximum flexibility to bring a host of products and applications to the market

I. Unlicensed Operations Are a Necessary Complement to Licensed Systems

Consumers seek solutions to a wide variety of communications needs. Providing the range of solutions required to meet these needs calls for different regulatory ground rules, just as it requires a multitude of hardware and software options. Traditionally, the Commission has provided for a broad range of solutions, and that heritage has generated many benefits for consumer, business and government users, as well as for equipment suppliers, system operators and their many employees. Licensed and unlicensed systems have all contributed to this heritage and success.

Licensed operations generally involve relatively expansive infrastructures needed to provide a requisite level of promised or even guaranteed reliability, coverage and features. Within the licensed category, some systems are dedicated to the specific communications needs of a given user while others provide communications to a broad group of users for a fee. At yearend 1995, Motorola estimates there were approximately 225 million wireless devices in service globally, operating on licensed paging, cellular, dispatch and PCS/PCN systems. Deployment of these systems requires a significant investment unlikely to be made under an unlicensed regime. The combination of factors including resources required, potential return on investment, and lack of control over the spectrum is not consistent with a cohesive economic business plan for such wide area systems.

In contrast, unlicensed operations solve a collection of communications needs that in all likelihood would go unmet if free and open consumer access to spectrum were not available. Inexpensive cordless phones, garage door openers, auditory assistance devices for the hearing impaired, baby monitors, wireless premise security cameras, and the recently authorized low cost family radios are all examples of the benefits unlicensed spectrum allocations offer. As the Commission provides the capability to support emerging broadband multimedia applications at 5

GHz, unlicensed operations can have an even greater benefit, both as standalone systems and as an adjunct to wired, cabled, and licensed wireless networks.

Therefore, Motorola supports the proposed allocation of 350 MHz of spectrum in the 5.15-5.35 and 5.725- 5.875 GHz bands. This proposed allocation offers the potential for open entry, equal access, innovation and flexibility. In addition to the domestic benefits, such an allocation will help establish U.S. leadership in an ever-increasing global market for telecommunications products. If the Commission resists the temptation to overly regulate the proposed allocation, this spectrum will provide the basis for development of a broad range of new consumer-oriented multimedia products.

II. A Listen Before Talk Etiquette Would Be Both Unnecessary and Detrimental at 5 GHz

Motorola recommends the Commission delete its proposed rule which requires unlicensed devices operating at 5.2 and 5.8 GHz to employ a listen-before-talk (LBT) etiquette. As detailed below and in Appendix A, we believe such an LBT requirement, patterned after that previously adopted for the 1.9 and 2.39 GHz unlicensed PCS bands, would be ineffective in controlling interference for broadband applications operating in the substantially higher 5 GHz band. Further, in our view, the proposed LBT rule requirement would be detrimental both in terms of spectral efficiency and in terms of unduly restricting the utility which manufacturers of 5 GHz multimedia devices could offer to consumers. Such product restrictions would negatively impact the applicability of advanced protocols such as ATM, the delivery of real time video, the use of one way links and the option of paired frequency systems.

The remainder of Section II addresses in detail concerns with an LBT requirement at 5 GHz. A potentially more practical option at 5 GHz to control interference, promote spectrum sharing and achieve fair access is to regulate RF power spectral density, by limiting transmitter power per kHz. Motorola addresses this alternative to an LBT more fully in Section III of these comments.

A. The Proposed LBT Requirement Would Be Ineffective In Controlling Interference and would Reduce Efficiency In The 5 GHz Band

In its rules adopted for the 1910-1930 and 2390-2400 MHz unlicensed PCS bands, the Commission requires use of a listen-before-talk (LBT) etiquette aimed at providing fair access to the spectrum and minimizing interference among users in the same area. Other unlicensed bands, e.g., 2400-2483.5 MHz, have no such LBT requirement.

The LBT requirement in the 1.9 and 2.39 GHz UPCS bands has been generally perceived as necessary to yield effective spectrum sharing. This concept was developed with the idea that unlicensed wireless PBX's and LAN's operating in those bands would routinely use omnidirectional antennas. As concluded in Appendix A, the LBT rule is effective in reducing the occurrence of interference approximately 50 percent of the time in the 2 GHz bands. Moreover, this estimated level of interference avoidance is achieved without the expectation of significant unnecessary LBT deferrals. As discussed in Appendix A, an unnecessary deferral refers to the potential of an LBT etiquette rule to cause a transmitter to defer when no actual interference would have occurred if its transmission had been allowed to take place.

Unfortunately, the anticipated success of the LBT rule in the 2 GHz band, i.e., interference avoidance without undue disruption of system operation, does not translate to the 5 GHz band. As discussed in Appendix A, directional antennas under the control of diversity algorithms, will be prevalent in the 5 GHz band. Motorola believes directional antennas will be in wide spread use in the 5 GHz unlicensed band because they represent an inexpensive means to offset the vulnerability to multipath distortion and coverage restrictions inherent with the higher data rate applications foreseen at 5 GHz.

The combination of diversity algorithms and directional antennas will provide the means to select one of several possible paths from a transmitter to a receiver. Such an approach not only provides adequate signal strength and protection from multipath distortion, but also provides a much lower potential for interference. Therefore, at 5 GHz proper use of steerable or selectable directional antennas along with reasonable control over RF power spectral density, is seen as a more likely and useful tool than a LBT etiquette in avoiding interference.

In addition, Motorola believes many wireless networks will have the ability to monitor spectral availability on a broad scale basis and utilize this information to avoid interference. Whereas a simple LBT function would operate on the basis of the power level detected by a single unit over a very short period of time, a network of distributed transceivers provides the means for very thorough monitoring of spectral activity on a space-time-frequency basis. Using this information, a wireless network can incorporate a dynamic spectrum management approach which not only avoids interference, but uses available bandwidth for maximum throughput, capacity and spectral efficiency.

As discussed in Appendix A, widespread use of directional antennas would result in a low correlation between LBT detection and the potential for interference avoidance. A high correlation is required for the LBT etiquette to provide utility. Fundamentally, an undesired signal source with a directional antenna adhering to a LBT requirement would need to have its antenna pointed at the sender of a desired signal occupying an RF channel to activate the LBT deferral function. This "undesired signal source," however, is not an interference threat to the communications in progress unless its antenna is pointed towards the receiver of the desired signal, which is likely to be in a different direction. In short, the need for directional antennas to provide reliable communications obviates the need for an LBT requirement.

B. The Proposed LBT Rule Would Inhibit the Flexibility to Provide a Full Range of Unlicensed Multimedia Solutions

Use of an LBT etiquette in the 5 GHz band unfortunately would inhibit some system and product concepts that may be quite effective in serving the public's need for low cost, on-premise and on-campus communications. For example, use of an LBT would hamper the use of protocols such as ATM and implementation of real time applications, one-way multimedia systems and two way wireless systems with separate subbands for mobile and access point transmissions. The remainder of this section addresses these issues in more detail.

1. ATM

Asynchronous Transfer Mode (ATM) is rapidly becoming the protocol of choice for high data rate systems, especially when it is necessary to service a wide range of communications needs such as video, voice, and data. Currently, there is considerable interest in providing a wireless complement to ATM. Utilization of the ATM technology in the unlicensed 5 GHz bands could dramatically accelerate the benefit the public will derive from the proposed allocation because of the availability of compatible ATM components and systems. An LBT rule appears to be totally incompatible with the ATM protocol for two very fundamental reasons:

- At 25 Mb/s, which is typical of the data rates being considered for the 5 GHz unlicensed band, an ATM cell is only 17 microseconds long. (For practical reasons an RF ATM cell might be a few microseconds longer.) The proposed LBT timing with respect to channel monitoring is 50 microseconds, and with respect to response time is 35 microseconds. Such timing parameters are inappropriate for an environment where the packets or cells are approximately 20 microseconds. For the protocol to operate as planned, packet transmissions would need to be much longer than the ATM cells.

- The ATM concept can utilize a reservation system to organize the delivery of cells. If however, an LBT rule is applied with priority over the ATM timing system, then LBT deferrals would frustrate the basic operation of the ATM network. The situation might be salvageable if all nodes in a ATM wireless network responded in a synchronized manner to LBT deferrals, but that is not possible since the LBT deferral process is made on the basis of individual units.

2. Real time or time bounded services

An LBT etiquette would be incompatible with applications such as real time voice, real time video or video where the cost of buffer storage at the receiver is prohibitively expensive. The LBT mechanism would interrupt the required continuous flow of information. For the residential market, multimedia links would typically be short, the desired signal would be strong and the propensity for nuisance LBT disruptions from distant devices could be significant. However, the geographical isolation of systems from one residence to another and the use of directional antennas coupled with the option to utilize alternate segments of the RF band, suggest that the actual vulnerability to harmful interference would be minimal. Therefore, the potential negative impact of an LBT requirement outweighs its perceived benefits.

3. One-way links

In effect, the LBT rule requires that each transmitting device incorporate a receiver that can detect signals on the same frequency and of the same bandwidth as the transmit signal. For a product or system concept that would otherwise not require a receiver at the same location or would otherwise have a receiver on a different frequency or of a different bandwidth, the LBT rule represents a significant burden in terms of providing cost effective solutions responsive to consumer demands.

4. Paired Frequency Option

Motorola recognizes that in some system applications it may be appropriate for wireless data systems to operate on paired frequencies. In such systems, a transceiver would transmit on one frequency and receive on a different frequency. Since the LBT rule requires a transceiver to monitor a channel before it transmits on that channel, an LBT rule is basically incompatible with the utilization of paired frequency systems. As discussed in Appendix B, there are two potential benefits to paired frequency applications in the 5 GHz band. The first is the economy of transceiver product cost and the second is spectral efficiency in some system configurations. This is a configuration at 5 GHz which was generally of no concern in the 2 GHz unlicensed PCS bands as paired frequency operation was not viable in the narrow 10 MHz asynchronous UPCS band[1].

Summary

In summary, Motorola recommends the Commission refrain from requiring an LBT etiquette for the 5 GHz band. There is little correlation between the proposed LBT detection and actual interference avoidance and the use of an LBT etiquette in this band will lead to significant efficiency and throughput data rate loss. Moreover, interference can be more directly avoided by the use of directional antennas and diversity algorithms likely to be prevalent at 5 GHz in order to provide reliable operation. An LBT etiquette would also retard the flexibility to offer a full range of unlicensed multimedia products responsive to the market because of the overhead implications of an intersystem LBT etiquette requirement.

1 It is conceivable that with 10 MHz now available for asynchronous operation both at 1910 and at 2390 MHz, paired frequency operations is now a potential consideration where it was not with the original 10 MHz allocation at 1910 MHz.

III. The Rules Should Allow Up to 1 Watt Transmitter Output Power and Use of Directional Antennas

The Commission proposed to limit EIRP to 100 mW in both the 5.2 and 5.8 GHz bands, but raised the possibility of increasing power at 5.8 GHz to 1.0 Watt EIRP. The NPRM solicited comments on several issues related to interference control, including limits on transmit power and antenna gain.

Motorola recommends that the Commission modify its proposal by regulating transmitter output power rather than EIRP, allowing gain antennas and using a power density approach. Specifically, we recommend the Commission adopt a transmitter output power limit of 250 mW at 5. 2 GHz and 1.0 Watt at 5.8 GHz, for bandwidths above a certain threshold, e.g., 25 MHz or greater. 2 We also recommend the Commission allow transmitter antenna gain up to 23 dB in both bands without any associated reduction in transmitter power output.

For bandwidths lower than the reference threshold, it may be appropriate to require that the maximum power be reduced in direct proportion to the bandwidth. For example, when a 10 MHz bandwidth is used, the transmitter could be limited to 0.4 W at 5.8 GHz. Such a power spectral density approach will help control interference. The specific details of such a proposal might best be resolved by an industry based committee. Such a committee should also address the possibility of specific considerations appropriate for community network applications.

Further, for fixed community network links, we recommend the rules specify a reduction of only 1 dB of transmitter power for each 3 dB of antenna gain above 23 dB, consistent with the

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2 The Commission proposed to limit power at 5.2 GHz to 100 mW largely over concern whether unlicensed operations could share with satellite links in portions of that band. To the extent such sharing is shown to be feasible, Motorola would support raising the power at 5.2 GHz beyond the 100 mW limit as well. It is our understanding that WINForum is addressing the interference issues and is recommending a 250 mW limit at 5.2 GHz.

approach the Commission proposed in ET Docket 96-8 addressing changes to the antenna gain limits for 5.8 GHz band part 15 spread spectrum point-to-point operations. 3

Motorola is concerned about controlling the level of interference that an unlicensed transmitter might generate. At the same time, expressing power limits in this band in terms of EIRP unnecessarily limits the ability to use directional antennas likely to be needed for reliable communications at 5 GHz. The effect of the Commission's proposal is that directional and omni antennas of equal peak EIRP are treated as having equal interference potential. That is not the case. The omni antenna is radiating power in all directions while the directional antenna is transmitting the same total power but it all emanates in one direction, leaving the spectrum in other directions available to other users. As discussed in Appendix C, both the goals of avoiding interference and allowing the use of directional antennas can be met, as such directional antennas can actually reduce the potential for interference in this band.

With respect to controlling interference, specifying a power spectral density (PSD) is also a very significant technique. For example, in the ISM bands the Commission authorizes unlicensed transmitters with up to 1 Watt of transmitter power provided spread spectrum techniques are used to spread the bandwidth of the radiated RF power. This rule is based upon the concept that power spectral density is the real determinant of potential interference among multiple non-interoperable systems. To a non interoperable device, interference is measured in terms of the undesired signal level above that of ambient thermal noise, which is approximately -174 dBm/Hz for room temperature applications. Therefore, RF power per Hz bandwidth is the critical parameter in terms of controlling interference.

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3 The Commission has an outstanding proposal in ET Docket No. 96-8, adopted February 5, 1996, which would permit greater than 6 dBi of antenna gain in the 5.8 GHz ISM band. Under the proposal, a maximum gain is not specified, but transmitter output power would be reduced by one dB for every 3 dB of antenna gain above 6dBi. The Commission also requested comment on allowing antenna gain greater than the curent 6 dBi limit in the 2.4 GHz ISM band and some commenters have supported that approach.

Unlicensed direct sequence spread spectrum, DSSS, transmitters in the ISM bands are authorized to use 1 watt of transmitter power with a minimum spectral bandwidth of 500 kHz. This represents a power spectral density of 0.5 mWatt per kHz. In addition, 6 dB of antenna gain is allowed. In terms of EIRP/kHz, the 5.8 GHz ISM band limit is therefore 2 mWatt per kHz.

Based on an EIRP power spectral density of 2 mWatts/kHz, a nominal 25 MHz transmission bandwidth, and 1 Watt of RF power, the allowable antenna gain should be 23 dB. This would yield the same potential interference as a 5.8 GHz ISM DSSS device in terms of power level relative the thermal noise floor (kTB).

In the 5 GHz band, the industry goal is to establish rules which provide for successful on-site and campus environment broadband multimedia communications such as high speed data and video. In Motorola's view, the recommendations set forth above regarding power and antenna gain help accomplish that goal.

IV. The Rules Should Allow Full Channelization Flexibility and Bandwidth on Demand

The Commission proposed not to require a specific channelization, but raised the question whether channelization of 25 MHz with aggregation of up to 3 channels would be preferable. Given the broad variety of multimedia applications this band may support, Motorola recommends the Commission allow full flexibility to determine channelization on a product-by-product or even a dynamic and variable "bandwidth on demand" basis. To this end, channelization should be allowed but not required. At this point in time it is too difficult to determine a definition of channelization and a recommendation that would not be potentially restrictive of future innovation. The power density approach recommended by Motorola in the previous section recognizes that the primary anticipated uses of this band is for broadband communications, but stops far short of specifying a particular bandwidth which must be used.

V. A One Bit/Sec/Hz Efficiency Standard Should Not be Required

The issue of spectrum efficiency is important to consider. Motorola supports the basic concept of efficient use of the spectrum but in a more general framework than suggested by a bit/sec/Hz criteria. Such a criteria measures only one factor contributing to the efficiency of spectrum use. For example, the Commission has long considered CDMA to be an efficient access technique. A specific CDMA transmitter, however, would fail the 1 bit/sec/Hz efficiency test. A bit/sec/Hz criteria, therefore, may actually restrict the development of systems that are quite spectrally efficient on a total system basis even though they may not be spectrally efficient if evaluated on the basis of bits/sec/Hz for individual transmitters.

In reality, the important spectral efficiency issue is spectral reuse. This leads to consideration of such measurements as bits/Hz/unit-area. In terms of modulation formats, those that feature a high index of modulation, i.e., low bits/Hz criteria, actually have superior interference rejection (lower C/I specification). The lower the C/I specification, the fewer the number of cells that need to be used in a repeat pattern and therefore the greater the frequency reuse. A bit/sec/Hz efficiency standard, however, incorporates no consideration of frequency reuse. Therefore, Motorola recommends against adoption of such a specification.

VI. Motorola Supports the Proposed Presumption of Non-Interference

Generally, intentional radiators operated under Part 15 of the rules are considered to operate on a "non-interference only basis" from a legal perspective. If such devices cause interference to other higher status services which share the spectrum, the Commission could require that operations of unlicensed devices cease. In actuality, the practical risk of interference is generally minimal with proper product design, but the uncertain legal status can chill a manufacturer's interest in the development of new technology and a user's interest in purchasing products.

For this reason, some manufacturers have suggested that the Commission create a new "Part 16" of the rules which would provide a higher status to all such devices. As noted in the proposal, however, there is some question whether the Communications Act allows the Commission to take this step. In Motorola's view, the Commission's alternative proposal to provide a "safe harbor" mechanism within Part 15 under which NII/SUPERNet devices would be presumed not to interfere if operated indoors or with antennas no more than 15 meters high outdoors is a reasonable solution to this issue.

VII. The Commission Should Streamline Approval of All Products, Including 5 GHz Devices

Timeliness to market is one of the most critical issues manufacturers face today. Accordingly, Motorola and other manufacturers spend significant resources on developing processes which help speed the design and manufacture of products. For some classes of products, development of a new model which previously required two years may now take a matter of months. Therefore, the regulatory process which defines how soon a manufacturer can place its product on the market is of critical concern.

In a separate proceeding on improving a number of the Commission's processes, Motorola made recommendations which would lead to faster market entry for all products now subject to Commission laboratory approval. 4 Minimizing the costs and delays of such regulatory approvals worldwide is a critical issue of interest to practically all manufacturers.

4 Comments of Motorola filed March 15, 1996 in PP Docket No. 96-17.

Motorola therefore recommends the Commission take this opportunity to streamline the equipment approval process to be applied to all products, including 5 GHz band devices.

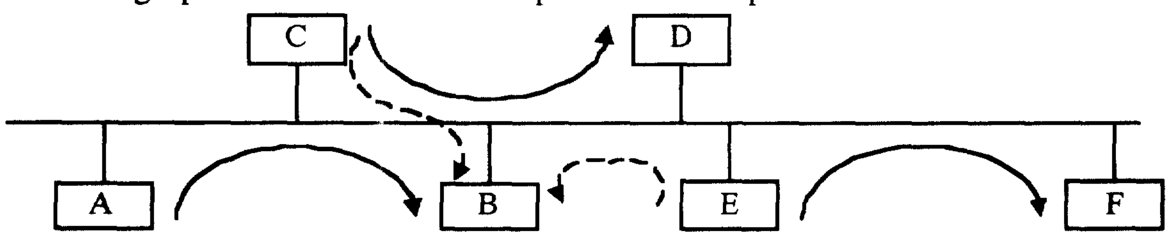
VIII. Conclusion

Motorola supports the proposed 350 MHz allocation at 5 GHz to provide for a full range of broadband multimedia on-site and on-campus communications products and systems. By refraining from requiring an LBT etiquette and by modifying its proposed power and antenna gain limits as discussed herein, the Commission will set the stage for the maximum benefit from this allocation.

Appendix A- LBT Discussion

Basic Concept of LBT

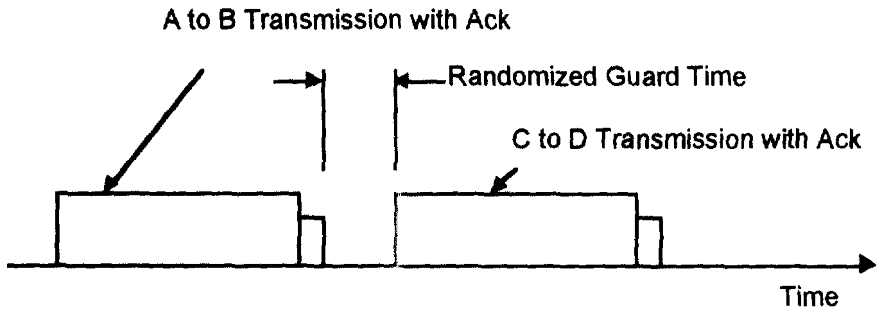
A wireline communications channel provides the means to discuss the listen before talk, LBT, etiquette from an idealized standpoint. This is a useful first step before considering the more complex issues of LBT operation on a wireless channel. This situation is depicted in Figure A1, where A is transmitting a packet to B and where C is poised to send a packet to D.



Wireline Packet Communications

Figure A1

Solid lines represent desired communications paths, whereas dashed lines indicate potential paths of interference to B. Before transmitting its packet, C observes the wireline channel and determines that the channel is busy with the packet being transmitted from A to B. According to the LBT rule, C waits for A to complete its transmission. After the A to B packet is completed, including a possible acknowledgment from B to A, C begins its transmission of a packet to D, but not before it waits a suitable guard time, as shown in Figure A2.



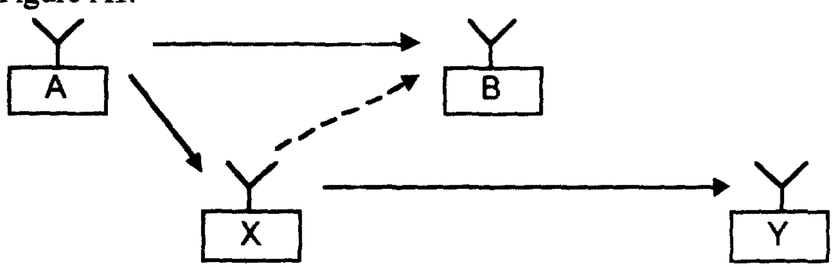
Wireline Packet Communications with LBT Protocol

Figure A2

The guard time indicated in Figure A2 is based on a random number in order to reduce the possibility that another sender, say E, which is also waiting for the A transmission to be completed, would begin its transmission at precisely the same time, thus causing a collision.

LBT Applied to a Wireless RF Etiquette at 2 GHz

The LBT etiquette has been applied to the UPCS bands at 1.9 and 2.39 GHz. Figure A3 illustrates a typical scenario were the LBT etiquette performs the desired function of preventing a collision of two data packet transmissions under the same scenario as discussed for the wireline case in Figure A1.

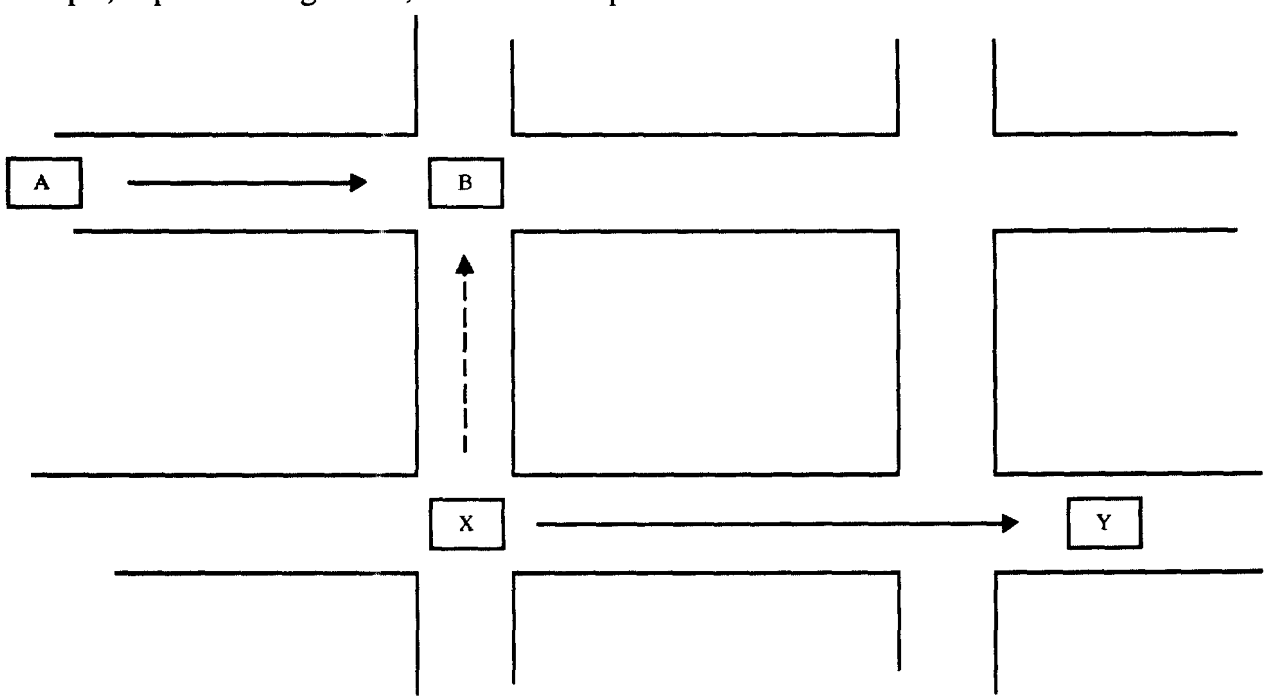


RF LBT Etiquette Prevents Interference

Figure A3

In this scenario A is transmitting a packet to B. Note that A and B belong to the same interoperable system that, for example, might use FSK at a data rate of 3 Mb/s. In this figure and the figures that follow X and Y belong to a different interoperable system, for example, PSK at 5 Mb/s. In the scenario of Figure A3, X is located approximately midway between A and B. In this location, X can monitor the RF channel, detect the presence of the transmission from A and defer its transmission until the transmission from A is completed. Note that X is monitoring the RF power level transmitted by A: X can not necessarily demodulate the data transmitted by A.

There is an important distinction to be made between the LBT etiquette applied to a wired channel as opposed to a wireless RF channel. That distinction is that the RF environment does not necessarily provide the opportunity for all users of the RF channel to detect the presence of other users of the wireless RF channel even when all users of the channel use omnidirectional antennas. A simple corridor example, depicted in Figure A4, illustrates this phenomena.

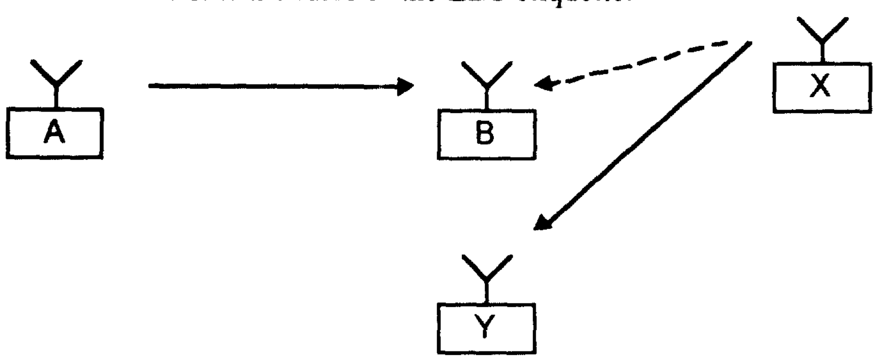


Hallway Scenario

Figure A4

In this example, A is transmitting to B. Because of the nature of RF propagation in the corridor geometry, X is not able to detect the presence of the transmission from A, i.e., the signal from A does not effectively "turn the corner" at B as well as it propagates down a straight corridor. X therefore transmits its signal to Y. Recalling that all antennas are assumed to be omnidirectional, the signal from X also propagates to B. B therefore receives both the desired signal from A and the undesired signal, interference, from X at approximately equal strength. As a consequence, B is not able to successfully demodulate the desired transmission from A.

Figure A5 depicts the generalized scenario of Figure A4 which is an unavoidable limitation of the UPCS LBT etiquette, i.e., X may be too far or too isolated in an RF sense from A to detect A's transmission under the rules of the LBT etiquette.

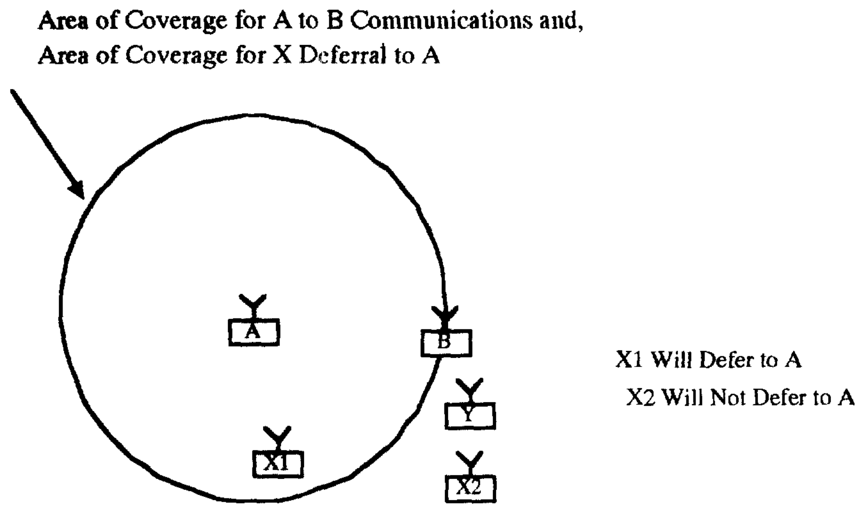


RF LBT Etiquette Not Able to Prevent Interference

Figure A5

Hence X will not defer to A. X will therefore transmit to Y while A is transmitting to B. X's transmission, given the scenario depicted in Figure A5, could interfere with B's ability to receive the transmission from A. This leads to the conclusion that the LBT etiquette applied to the UPCS 2 GHz RF wireless environment is effective in limiting some, but not all, potential sources of interference.

In order to explore this result one step further, some coarse estimates for the relative ranges involved may be useful. The 2 GHz LBT rule requires a sensitivity of better than 32 dB above thermal noise (kTB). If one considers the sensitivity of a diversity data receiver including a fade margin (with non-directional antennas) a similar number is typically found. Thus, LBT sensitivity and useful data sensitivity are expected to be similar specifications. This condition is depicted in Figure A6 where the communications range is approximately equal to the LBT range.



Coverage From A with Omni Antennas

Figure A6

Utilizing practical experience with in-door wireless systems incorporating diversity with non directional antennas, it is found that the useful range, such as A to B in Figure A5 is less than the distance X to B from which an interferer of similar design, X, could significantly effect the A to B range. In other words, for B to receive a desired signal from A the signal strength from A must be stronger than the interference strength from X5. In an indoor office environment, a distance ratio of 2:1 is a reasonable estimate. This scenario is depicted in Figure A7.

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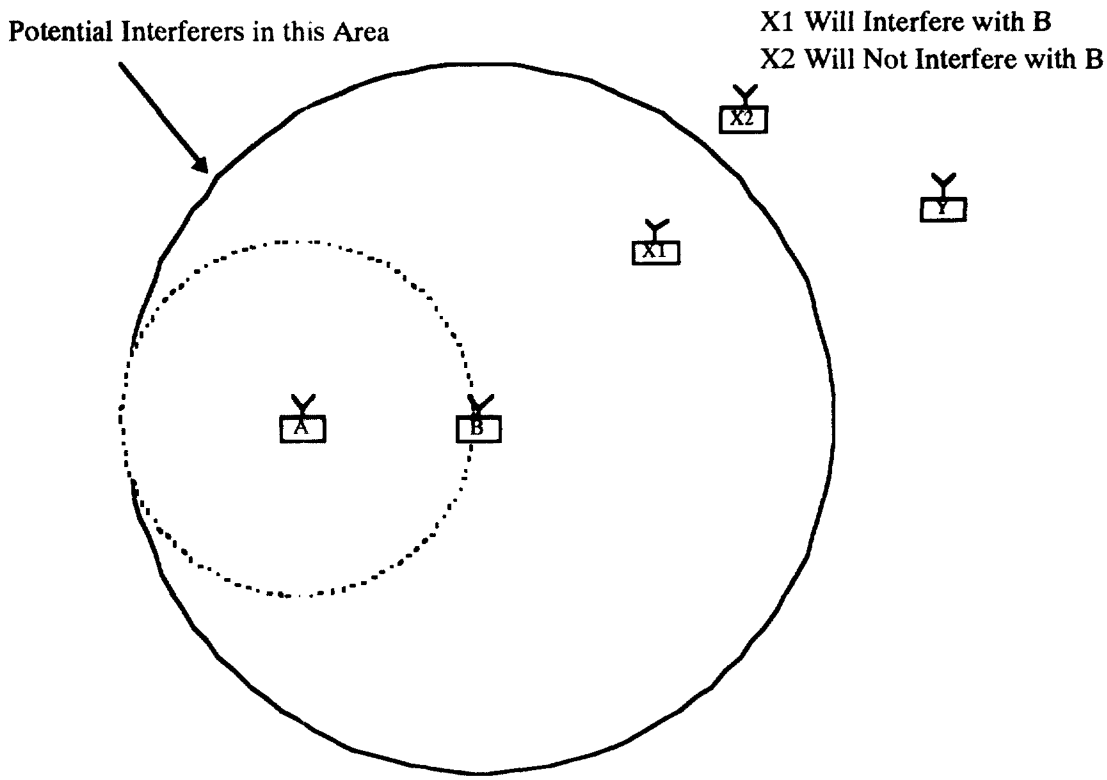
5 The specific ratio depends on many details. Direct Sequence Spread Spectrum, DSSS, is an example where the interference range could actually be less, but DSSS is not necessary attractive for high data rate applications.



Interference Potential with Omni Antennas

Figure A7

The dashed line circle indicates the area within which a potential interferer would defer to a transmission from A. The solid line circle indicates the area from which an interfering transmitter could cause noticeable interference to the A to B link.

Two conclusions result from this observation.

1. In the main, transmissions that are deferred by the 2 GHz LBT etiquette function, would have caused interference if they had not been deferred, and
2. The effectiveness of the LBT etiquette is limited by the fact that the interference range is typically greater than the LBT deferral range. The example depicted in Figure A7 would indicate that the LBT etiquette eliminates 25% of the potential sources of interference. Actually, the result may be closer to 50 % for indoor applications since the idealized large

circle centered at B does not consider the usual occurrence of exterior walls and major building partitions that block the propagation of RF signals. This result could be translated into an estimate of reducing the potential interference by 1/2 or 3 dB.

LBT Applied to a Wireless RF Etiquette at 5 GHz

The successful result illustrated here, however, does not translate to the 5 GHz band when one assumes that directional antennas with diversity algorithms will be prevalent. The example considered above will be expanded below to illustrate the impact of directional antennas which are not only more practical at 5 GHz than at 2 GHz because of the shorter wavelength, but in Motorola's view, will be required to successfully transmit high data rate traffic. The issue of interference aside for a moment, gain antennas at both the transmitter and the receiver provide two important functions:

1. It is noted that 1 Mb/s LAN products at 2.4 GHz will soon set the wireless LAN range or coverage distance expectation of the user community. Although it is anticipated that new systems at 5 GHz will provide 20 times the data rate, the combined effect of higher data rates and higher operating frequency will result in a significant loss of range unless gain antennas at both transmitter and receiver are used with diversity algorithms. Thus, gain antennas at both the transmitter and receiver will be required to meet the user's anticipation of range.
2. Intersymbol multipath distortion will be a greater concern with high data rate transmissions than with lower data rate 2 GHz applications. With omni antennas there will exist many paths between a transmitter and receiver, some of which involve reflections of walls, for instance, in an indoor environment. The propagation time of these individual paths will be different, i.e., typically as much as 50 to 100 nanoseconds for indoor applications. With bit periods of 50 nanoseconds (bit period of a 20 Mb/s signal) the summation of these signals arriving with such large differential delays results in a highly distorted signal waveform, i.e., intersymbol interference. Directional antennas reduce the number of paths from transmitter